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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. _____

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Steven Francis	LeBoeuf	Raleigh, North Carolina
Michael Edward	Aumer	Raleigh, North Carolina

Additional inventors are being named on the _____ separately numbered sheets attached hereto.

TITLE OF THE INVENTION (500 characters max):

 METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES

Direct all correspondence to: **CORRESPONDENCE ADDRESS**
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 OR
☐ Firm or Individual Name
 Address

City	State	Zip
Country	Telephone	Email

ENCLOSED APPLICATION PARTS (check all that apply)
☒ Application Data Sheet. See 37 CFR 1.76. ☐ CD(s), Number of CDs _____
☒ Drawing(s) Number of Sheets 13 ☐ Other (specify) _____
☒ Specification (e.g., description of the invention) Number of Pages 23

Fees Due: Filing Fee of \$260 (\$130 for small entity) (\$65 for micro entity). If the specification and drawings exceed 100 sheets of paper, an application size fee is also due, which is \$400 (\$200 for small entity) (\$100 for micro entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

METHOD OF PAYMENT OF THE FILING FEE AND APPLICATION SIZE FEE FOR THIS PROVISIONAL APPLICATION FOR PATENT
☐ Applicant asserts small entity status. See 37 CFR 1.27.
☐ Applicant certifies micro entity status. See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
☐ A check or money order made payable to the *Director of the United States Patent and Trademark Office* is enclosed to cover the filing fee and application size fee (if applicable). 260
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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 10 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 2 of 2

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.	
☒	No.
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☐	Yes, the invention was made under a contract with an agency of the U.S. Government. The name of the U.S. Government agency and Government contract number are: _____

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Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

SIGNATURE *NJ Boddie II* DATE 09-27-2014
TYPED OR PRINTED NAME Needham J. Boddie, II REGISTRATION NO. 40,519
(if appropriate)
TELEPHONE 919-854-1400 DOCKET NUMBER 9653-30PR

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	9653-30PR
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
--------------------------	---

Inventor Information:

Inventor 1						Remove	
Legal Name							
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	Steven		Francis		LeBoeuf		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service							
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Inventor 2						Remove	
Legal Name							
Prefix	Given Name		Middle Name		Family Name		Suffix
	Michael		Edward		Aumer		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service							
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Address 2							
City	Raleigh		State/Province	NC			
Postal Code	27608		Country i	US			
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.							

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9653-30PR
	Application Number	
Title of Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES	

☐ An Address is being provided for the correspondence information of this application.

Customer Number	20792		
Email Address	instructions@myersbigel.com	Add Email	Remove Email

Application Information:

Title of the Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES		
Attorney Docket Number	9653-30PR	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	13	Suggested Figure for Publication (if any)	

Filing By Reference :

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	9653-30PR
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the application number blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
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Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

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Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.



NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	9653-30PR
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES		

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☒ Authorization to Permit Access to the Instant Application by the Participating Offices

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Applicant Information:

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Applicant 1		
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.		
Clear		
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☒ Person to whom the inventor is obligated to assign.		☐ Person who shows sufficient proprietary interest
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:		
Name of the Deceased or Legally Incapacitated Inventor :		
If the Applicant is an Organization check here. ☒		
Organization Name	Valencell, Inc.	

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	9653-30PR
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES		

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Phone Number		Fax Number	
Email Address			
Additional Applicant Data may be generated within this form by selecting the Add button.			

Assignee Information including Non-Applicant Assignee Information:

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Assignee 1				
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
If the Assignee or Non-Applicant Assignee is an Organization check here. ☐				
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Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.				

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	9653-30PR
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES		

Signature:

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications.					
Signature				Date (YYYY-MM-DD)	2014-09-27
First Name	Needham J.	Last Name	Boddie, II	Registration Number	40519
Additional Signature may be generated within this form by selecting the Add button.					

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METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES

FIELD OF THE INVENTION

The present invention relates generally to monitoring devices and, more particularly, to monitoring devices for measuring physiological information.

5

BACKGROUND OF THE INVENTION

Photoplethysmography (PPG) is based upon shining light into the human body and measuring how the scattered light intensity changes with each pulse of blood flow. The scattered light intensity will change in time with respect to changes in blood flow or blood opacity associated with heart beats, breaths, blood oxygen level (SpO₂), and the like. Such a sensing methodology may require the magnitude of light energy reaching the volume of flesh being interrogated to be steady and consistent so that small changes in the quantity of scattered photons can be attributed to varying blood flow. If the incidental and scattered photon count magnitude changes due to light coupling variation between the source or detector and the skin or other body tissue, then the signal of interest can be difficult to ascertain due to large photon count variability caused by motion artifacts. Changes in the surface area (and volume) of skin or other body tissue being impacted with photons, or varying skin surface curvature reflecting significant portions of the photons may also significantly impact optical coupling efficiency. Physical activity, such as walking, cycling, running, etc., may cause motion artifacts in the optical scatter signal from the body, and time-varying changes in photon intensity due to motion artifacts may swamp-out time-varying changes in photon intensity due to blood flow changes. Environmental artifacts, such as ambient light noise, as well as motion-coupled ambient light

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noise can further swamp-out blood-flow related signals. Each of these changes in optical coupling can dramatically reduce the signal-to-noise ratio (S/N) of biometric PPG information to total time-varying photonic interrogation count. This can result in a much lower accuracy in metrics derived from PPG data, such as heart rate and breathing rate.

The signal quality from a biometric sensors, such as a PPG sensor, in a wearable monitoring device increases when the monitoring device is worn correctly and decreases when the monitoring device is worn incorrectly. For example, a user may go for a run with a biometric earbud and expect accurate heart rate zone information from the sensor(s) therein, only to find the sensor data is erroneous due to a poor fitting of the biometric earbud within the ear. Unfortunately, without some way to measure signal quality, a user may not know if sensor signal quality is adequate.

SUMMARY

It should be appreciated that this Summary is provided to introduce a selection of concepts in a simplified form, the concepts being further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of this disclosure, nor is it intended to limit the scope of the invention.

According to some embodiments of the present invention, a wearable biometric monitoring device is configured to assess the biometric signal quality of one or more sensors associated with the biometric monitoring device, determine how the user should adjust the device to improve the biometric fit, and instruct the user to wear the device a certain way (e.g., audio-visually via a remote device). In some embodiments, this may involve an iterative approach. In some embodiments, communicating instructions to a user may include instructing the user to execute a testing regimen while wearing the device. The testing regimen facilitates an estimation of a signal quality that can be used to provide feedback to the user that he/she needs to adjust the device to improve the biometric fit (and hence the biometric signal quality).

According to some embodiments of the present invention, a method of monitoring signal quality of a wearable biometric monitor having at least one sensor configured to detect and/or measure physiological information

from a subject wearing the biometric monitor and at least one processor coupled to the at least one sensor that is configured to receive and analyze signals produced by the at least one sensor includes instructing the subject via the at least one processor to begin an exercise regimen, measuring signal quality
5 produced by the at least one sensor during the exercise regimen, and communicating information to the subject regarding the signal quality during the exercise regimen. In some embodiments, the biometric monitor is configured to be integrated within an earbud. In some embodiments, the biometric monitor is configured to be integrated within an audio headset, a wrist strap, a wrist watch,
10 an ankle bracelet, or an armband. In other embodiments, the biometric monitor comprises a band that configured to at least partially encircle a portion of the body of a subject, such as a limb, a nose, an earlobe, and/or a digit, etc.

In some embodiments, instructing the subject to begin an exercise regimen comprises sending an audio and/or visual communication to a remote
15 device in communication with the biometric monitor. In other embodiments, instructing the subject to begin an exercise regimen comprises causing the biometric monitor and/or a remote device to vibrate.

Communicating information to the subject regarding the signal quality may include communicating instructions to the subject to adjust the
20 biometric monitor relative to the body of the subject if the signal quality is below a threshold level. Communicating information to the subject regarding the signal quality also may include communicating information to the subject that the signal quality is above a threshold level.

In some embodiments, communicating information to the subject
25 regarding the signal quality comprises sending an audio and/or visual communication to a remote device in communication with the biometric monitor. In other embodiments, communicating information to the subject regarding the signal quality comprises causing the biometric monitor and/or a remote device to vibrate.

30 In some embodiments, the biometric monitor includes an actuator, and the method further comprises automatically adjusting the biometric monitor relative to the body of the subject via the actuator if the signal quality is below a threshold level.

In some embodiments, the biometric monitor includes a motion

sensor, and the method further comprises determining if the subject has begun the exercise regimen by detecting a change in subject activity via the motion sensor.

5 It is noted that aspects of the invention described with respect to one embodiment may be incorporated in a different embodiment although not specifically described relative thereto. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination. Applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to be able to amend any originally filed claim to
10 depend from and/or incorporate any feature of any other claim although not originally claimed in that manner. These and other objects and/or aspects of the present invention are explained in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

15 The accompanying drawings, which form a part of the specification, illustrate various embodiments of the present invention. The drawings and description together serve to fully explain embodiments of the present invention.

Fig. 1 is a block diagram of a wearable biometric monitoring device that can communicate with a remote device, such as a smartphone, according to
20 some embodiments of the present invention.

Fig. 2 illustrates a biometric monitoring device that can be positioned within an ear of a subject, according to some embodiments of the present invention.

Fig. 3 illustrates a biometric monitoring device that can be
25 positioned around an appendage of the body of a subject, according to some embodiments of the present invention.

Fig. 4 is a flowchart of operations for monitoring and improving signal quality of a wearable biometric monitor, according to some embodiments of the present invention.

30 Figs. 5A-5B, 6A-6B, 7A-7B and 8A-8B illustrate communications sent to a user in the form of graphical illustrations, according to some embodiments of the present invention.

Fig. 9 is a graphical illustration of a time-domain PPG waveform produced by a wearable biometric monitoring device according to some

embodiments of the present invention and where there are negligible motion artifacts associated with the waveform.

Fig. 10 is a graphical illustration of a time-domain PPG waveform produced by a wearable biometric monitoring device according to some
5 embodiments of the present invention and where there are substantial motion artifacts associated with the waveform.

Fig. 11A illustrates an exemplary spectrogram of a PPG signal from a user wearing a biometric monitoring device according to some
embodiments of the present invention and without active motion noise removal.

10 Fig. 11B illustrates the removal of motion noise from the spectrogram of Fig. 11A via one or more filters.

Fig. 12 is an exemplary plot of signal quality Qs over time for an exemplary run by a user wearing a biometric monitoring device according to some embodiments of the present invention.

15 Fig. 13 is a plot of signal quality Qs over time for a user conducting a self-fitting test, according to some embodiments of the present invention.

Fig. 14 is a plot of signal quality Qs over time for a user conducting an instructed "quick test" regimen, according to some embodiments of the present invention.

20 DETAILED DESCRIPTION

The present invention will now be described more fully hereinafter with reference to the accompanying figures, in which embodiments of the invention are shown. This invention may, however, be embodied in many
25 different forms and should not be construed as limited to the embodiments set forth herein. Like numbers refer to like elements throughout. In the figures, certain layers, components or features may be exaggerated for clarity, and broken lines illustrate optional features or operations unless specified otherwise. In addition, the sequence of operations (or steps) is not limited to the order
30 presented in the figures and/or claims unless specifically indicated otherwise. Features described with respect to one figure or embodiment can be associated with another embodiment or figure although not specifically described or shown as such.

It will be understood that when a feature or element is referred to

as being "on" another feature or element, it can be directly on the other feature or element or intervening features and/or elements may also be present. In contrast, when a feature or element is referred to as being "directly on" another feature or element, there are no intervening features or elements present. It will
5 also be understood that, when a feature or element is referred to as being "secured", "connected", "attached" or "coupled" to another feature or element, it can be directly secured, directly connected, attached or coupled to the other feature or element or intervening features or elements may be present. In contrast, when a feature or element is referred to as being "directly secured",
10 "directly connected", "directly attached" or "directly coupled" to another feature or element, there are no intervening features or elements present. Although described or shown with respect to one embodiment, the features and elements so described or shown can apply to other embodiments.

The terminology used herein is for the purpose of describing
15 particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

As used herein, the terms "comprise", "comprising", "comprises", "include", "including", "includes", "have", "has", "having", or variants thereof are
20 open-ended, and include one or more stated features, integers, elements, steps, components or functions but does not preclude the presence or addition of one or more other features, integers, elements, steps, components, functions or groups thereof. Furthermore, as used herein, the common abbreviation "e.g.", which derives from the Latin phrase "exempli gratia," may be used to introduce
25 or specify a general example or examples of a previously mentioned item, and is not intended to be limiting of such item. The common abbreviation "i.e.", which derives from the Latin phrase "id est," may be used to specify a particular item from a more general recitation.

As used herein, the term "and/or" includes any and all
30 combinations of one or more of the associated listed items and may be abbreviated as "/".

As used herein, phrases such as "between X and Y" and "between about X and Y" should be interpreted to include X and Y. As used herein, phrases such as "between about X and Y" mean "between about X and about

Y." As used herein, phrases such as "from about X to Y" mean "from about X to about Y."

Spatially relative terms, such as "under", "below", "lower", "over", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if a device in the figures is inverted, elements described as "under" or "beneath" other elements or features would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of over and under. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Similarly, the terms "upwardly", "downwardly", "vertical", "horizontal" and the like are used herein for the purpose of explanation only unless specifically indicated otherwise.

It will be understood that although the terms first and second are used herein to describe various features or elements, these features or elements should not be limited by these terms. These terms are only used to distinguish one feature or element from another feature or element. Thus, a first feature or element discussed below could be termed a second feature or element, and similarly, a second feature or element discussed below could be termed a first feature or element without departing from the teachings of the present invention.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

The term "about", as used herein with respect to a value or number, means that the value or number can vary by +/- 20%, 10%, 5%, 1%,

0.5%, or even 0.1%.

The terms "monitoring device" and "biometric monitoring device" are interchangeable and include any type of device that may be attached to or near the ear, to an appendage of a user, or to any other part of the body, and may have various configurations, without limitation.

The term "monitoring" refers to the act of measuring, quantifying, qualifying, estimating, sensing, calculating, interpolating, extrapolating, inferring, deducing, or any combination of these actions. More generally, "monitoring" refers to a way of getting information via one or more sensing elements. For example, "blood health monitoring" includes monitoring blood gas levels, blood hydration, and metabolite/electrolyte levels.

The term "headset", as used herein, is intended to include any type of device or earpiece that may be attached to or near the ear (or ears) of a user and may have various configurations, without limitation. Headsets incorporating biometric monitoring devices, as described herein, may include mono headsets (a device having only one earbud, one earpiece, etc.) and stereo headsets (a device having two earbuds, two earpieces, etc.), earbuds, hearing aids, ear jewelry, face masks, headbands, and the like. In some embodiments, the term "headset" may include broadly headset elements that are not located on the head but are associated with the headset. For example, in a "medallion" style wireless headset, where the medallion comprises the wireless electronics and the headphones are plugged into or hard-wired into the medallion, the wearable medallion would be considered part of the headset as a whole. Similarly, in some cases, if a mobile phone or other mobile device is intimately associated with a plugged-in headphone, then the term "headset" may refer to the headphone-mobile device combination. The terms "headset" and "earphone", as used herein, are interchangeable.

The term "physiological" refers to matter or energy of or from the body of a creature (e.g., humans, animals, etc.). In embodiments of the present invention, the term "physiological" is intended to be used broadly, covering both physical and psychological matter and energy of or from the body of a creature.

The term "body" refers to the body of a subject (human or animal) that may wear a monitoring device, according to embodiments of the present invention.

The term "processor" is used broadly to refer to a signal processor or computing system or processing or computing method which may be localized or distributed. For example, a localized signal processor may comprise one or more signal processors or processing methods localized to a general location, such as to a wearable device. Examples of such wearable devices may comprise an earpiece, a headpiece, a finger clip, a toe, a limb band (such as an arm band or leg band), an ankle band, a wrist, an nose band, a sensor patch, or the like. Examples of a distributed processor comprise "the cloud", the internet, a remote database, a remote processor computer, a plurality of remote processors or computers in communication with each other, or the like, or processing methods distributed amongst one or more of these elements. The key difference is that a distributed processor may include delocalized elements, whereas a localized processor may work independently of a distributed processing system. As a specific example, microprocessors, microcontrollers, or digital signal processors are a few non-limiting examples of physical signal processors that may be found in wearable devices.

In the following figures, various monitoring devices will be illustrated and described for attachment to the ear or an appendage of the human body. However, it is to be understood that embodiments of the present invention are not limited to those worn by humans.

The ear is an ideal location for wearable health and environmental monitors. The ear is a relatively immobile platform that does not obstruct a person's movement or vision. Monitoring devices located at an ear have, for example, access to the inner-ear canal and tympanic membrane (for measuring core body temperature), muscle tissue (for monitoring muscle tension), the pinna, earlobe, and elsewhere (for monitoring blood gas levels), the region behind the ear (for measuring skin temperature and galvanic skin response), and the internal carotid artery (for measuring cardiopulmonary functioning), etc. A particularly distinct pulsatile blood flow waveform can be discerned optically, via PPG, between the anti-tragus and concha region of the ear. The ear is also at or near the point of exposure to: environmental breathable toxicants of interest (volatile organic compounds, pollution, etc.); noise pollution experienced by the ear; and lighting conditions for the eye. Furthermore, as the ear canal is naturally designed for transmitting acoustical energy, the ear provides a good location for

monitoring internal sounds, such as heartbeat, breathing rate, and mouth motion.

Fig. 1 is a schematic diagram of a wearable monitoring device 10, according to some embodiments of the present invention. The wearable biometric monitoring device 10 may be an earbud module configured to be positioned within the ear of a subject, may be in the form of a sensor band configured to be secured to an appendage (e.g., an arm, wrist, hand, finger, toe, leg, foot, neck, etc.) of a subject, may be worn internally in the body (e.g., within the mouth as with a mouth guard, etc.), may be a sensor device configured to be adhesively secured to any portion of the body of a subject. Wearable monitoring devices, according to some embodiments of the present invention, may also be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, a headband, an armband, etc. Wearable monitoring devices, according to some embodiments of the present invention, may also be utilized in various devices and articles including, but not limited to, patches, clothing, etc. Embodiments of the present invention can be utilized wherever PPG and blood flow signals can be obtained and at any location on the body of a subject. Embodiments of the present invention are not limited to the illustrated monitoring devices.

Fig. 2 illustrates an exemplary monitoring apparatus 20 in the form of an earbud module. The illustrated apparatus 20 includes a housing 22 that is configured to be positioned within the ear of a subject, and that has a sensor region 24 configured to contact a selected area of the ear when the housing 22 is attached to the ear E. The illustrated sensor region 24 may be contoured (i.e., is "form-fitted") to matingly engage a portion of the ear between the anti tragus and acoustic meatus. However, monitoring devices in accordance with embodiments of the present invention can have sensor regions configured to engage various portions of the ear. For example, in some embodiments, the sensor region may be located at the earbud tip to fit within the ear canal of a subject. In some embodiments, the housing may be configured with one or more housing portions that come within proximity of other portions of the ear, such as the helix, anti-helix, pinna, tragus, behind the ear structure, in front of the ear structure, on top of the ear structure, below the ear structure, etc., and wherein a sensor region is also located in these housing portions.

Fig. 3 illustrates an exemplary monitoring apparatus 30 in the form

of a sensor band 32 configured to be secured to an appendage (e.g., an arm, wrist, hand, finger, toe, leg, foot, neck, etc.) of a subject, or to the head, hip, trunk of the subject, etc. The band 32 includes a sensor region 34 on or extending from the inside surface 32a of the band 32. In some embodiments, a device configured to be positioned within the body, such as a mouth guard, may comprise one or more sensor regions.

The sensor regions 24, 34 for the monitoring devices 20, 30 of Figs. 2 and 3 each include a sensor module (not shown) that is configured to detect and/or measure physiological information from the subject wearing the devices 20, 30. In some embodiments, the sensor module may be configured to detect and/or measure one or more environmental conditions in a vicinity of the subject wearing the monitoring device 20, 30. The sensor module may be an electromagnetic sensor module, such as an optical sensor module that includes at least one optical emitter and at least one optical detector. Exemplary optical emitters include, but are not limited to, light-emitting diodes (LEDs), laser diodes (LDs), compact incandescent bulbs, micro-plasma emitters, IR blackbody sources, or the like. Sensor modules in accordance with embodiments of the present invention may utilize other electromagnetic wavelengths, such as microwaves, radio waves, or terahertz waves, for example. In addition, the sensor module may include various types of sensors including and/or in addition to optical sensors. For example, the sensor module may include one or more inertial sensors (e.g., an accelerometer, piezoelectric sensor, vibration sensor, photoreflector sensor, etc.) for detecting changes in motion, one or more thermal sensors (e.g., a thermopile, thermistor, resistor, etc.) for measuring temperature of a part of the body, one or more electrical sensors for measuring changes in electrical conduction, one or more skin humidity sensors, and/or one or more acoustical sensors.

Referring back to Fig. 1, the various components of a wearable biometric monitoring device 10, according to embodiments of the present invention, are illustrated. The biometric monitoring device 10 includes one or more sensors 12 (e.g., one or more sensors in the sensor regions 24, 34 of the devices in Figs. 2 and 3), and at least one processor 14 that is coupled to the sensor(s) 12 and that is configured to receive and analyze signals produced by the sensor(s). The illustrated biometric monitoring device 10 also includes a

communication component 16 and an adjustment mechanism 18.

The communication component 16 allows the processor(s) 14 to communicate with a wearer of the biometric monitoring device 10 via a remote device 40, such as a smart phone, computer, etc. In some embodiments, the communication component 16 and processor component 14 may be integrated together, such as with a wireless processor, such as a Bluetooth chipset, WiFi chipset, ZigBee chipset, or the like.

The adjustment mechanism 18 may be any type of device that facilitates proper placement of the biometric monitoring device 10 relative to the body of the subject. Exemplary adjustment mechanisms 18 may include, but are not limited to, spacers, padding, straps, ear gel devices, ear stabilization pieces (such as pieces designed to fit within regions of the ear to stabilize an earbud within the ear), adjustment holes (such as the holes used to adjust a belt or wristband on the body via a bar or wedge that fits in the holes and secures the belt or band), ratcheting mechanism(s), spring mechanisms (such as structure that compresses a part of the housing or sensor region to the body of a subject), threaded mechanisms (such as a jackscrew, etc.), fluid compression mechanisms, air pumping mechanisms, etc. In some cases, the adjustment mechanism may be autonomous and may not require physical adjustment by the subject wearing the device.

It should be understood that the wearable device 10 may comprise all or only part of the illustrated components (i.e., sensor(s) 12, processor(s) 14, communication component(s) 16, or adjustment mechanism 18). In the case where the wearable device comprises only some of these components, the functionality of the remaining components may be realized all or in part by a remote device 40. The remote device may be in wired or wireless communication with the wearable device 10. Non-limiting examples of such remote devices may include a smartphone or other type of phone, a sensor hub, a computer, a smart pad, a cloud-based processing system, a wearable accessory, a control box, a "medallion", a smartwatch, smart glasses, etc.

Referring now to Fig. 4, operations for adjusting signal quality of one or more sensors of a wearable biometric monitoring device 10, according to some embodiments of the present invention, are illustrated. Initially, the wearer of a biometric monitoring device 10 is instructed via the processor(s) 14 to

initiate a signal quality test (Block 100). The signal quality test may involve various activities that result in motion noise. For example, the user may be instructed to run in place (or jump, dance, cycle, etc.) for a short time interval (e.g., a few seconds, etc.). The processor(s) 14 then determines the quality of the signal(s) from the sensor(s) of the biometric monitoring device 10 during the quality test regimen (Block 110). Additional operations associated with determining the signal quality may include determining if the biometric monitoring device 10 is being worn by the user and determining if the user is actually following the quality test regimen (i.e., running in place, etc.) by checking readings from one or more sensors in the device, such as a PPG sensor and/or an accelerometer associated with the biometric monitoring device 10.

Next, the processor(s) 14 determines what information to communicate to the wearer of the biometric monitoring device 10 (Block 120) and communicates this information to the user (Block 130). For example, the processor(s) determines whether the fit of the biometric monitoring device 10 is okay or whether the user needs to readjust the biometric monitoring device 10 in some way, and this information is communicated to the user. For example, if the biometric monitoring device 10 is positioned correctly (i.e., sensor signal quality is acceptable), the processor(s) 14 communicates this information to the user. If the biometric monitoring device 10 is not positioned correctly (i.e., sensor signal quality is not acceptable), the processor(s) 14 communicates this information to the user.

Information communicated to the user may be audibly and/or visually communicated. For example, Figs. 5A-5B, 6A-6B, 7A-7B, and 8A-8B illustrate various visual communications to a user regarding whether the fit of the biometric monitoring device 10 is okay or whether the user needs to readjust the biometric monitoring device 10 in some way. These visual communications may be made to the user via the wearable biometric monitoring device 10 and/or via a remote device 40 (e.g., a smartphone, computer, etc.) in communication with the biometric monitoring device 10.

Fig. 5A illustrates a communication sent to a user in the form of a graphical illustration 200 that a biometric monitoring device 10 in the form of an earbud is positioned inside the ear of the user at an incorrect angle. Fig. 5B illustrates a communication sent to a user in the form of a graphical illustration

202 that a biometric monitoring device 10 in the form of an earbud is positioned inside the ear of the user at the correct angle.

Fig. 6A illustrates a communication sent to a user in the form of a graphical illustration 204 that a biometric monitoring device 10 in the form of an earbud is positioned outside the ear of the user at an incorrect angle. Fig. 6B illustrates a communication sent to a user in the form of a graphical illustration 206 that a biometric monitoring device 10 in the form of an earbud is positioned outside the ear of the user at the correct angle.

Fig. 7A illustrates a communication sent to a user in the form of a graphical illustration 208a that a biometric monitoring device 10 in the form of an earbud is positioned correctly within the ear of a user. Fig. 6B illustrates a communication sent to a user in the form of a graphical illustration 208b that a biometric monitoring device 10 in the form of an earbud is positioned at an incorrect angle within the ear of the user.

Figs. 8A and 8B illustrate communications sent to a user in the form of graphical illustrations 210a, 210b with instructions for properly positioning a biometric monitoring device 10 in the form of an earbud within the ear of the user. For example, the graphical illustration 210a of Fig. 8A instructs the user to place the earbud inside the ear, and the graphical illustration 210b of Fig. 8B instructs the user to rotate the earbud forward such that the earbud arm fits between the intertragic notch and "locks" the sensor region of the earbud inside the ear.

The aforementioned examples of audio-visual communication to the user are illustrative only and not meant to be limiting. For example, if a PPG sensor is located at the tip of an earbud, and if the signal quality from that PPG sensor is deemed to be insufficient, the visual presentation to the user may suggest that the subject place the ear tip deeper in the ear, change the ear tip gel, rotate the tip, etc. Similarly, for the case of a band, such a wristband, comprising a PPG sensor, the visual presentation may suggest that the subject tighten the band, change the band fitting, rotate the band, etc.

Referring now to Fig. 9, a time-domain PPG waveform 300 is illustrated. The illustrated waveform 300 is from the sensor(s) within a biometric monitoring device 10 worn by a user and illustrates the condition where there are negligible motion artifacts associated with the waveform as a result of user

motion, footsteps, breathing, etc. The illustrated waveform 300 illustrates two heartbeats of the user. Fig. 10 illustrates a time-domain PPG waveform 302 from the sensor(s) within a biometric monitoring device 10 worn by a user where there are substantial motion artifacts. The actual heart beat waveform 300 is illustrated in dotted line and is masked by the substantial motion artifacts.

Fig. 11A illustrates an exemplary spectrogram 400 of a PPG signal from a user wearing a biometric monitoring device 10 and without active motion noise removal. The spectrogram 400 includes, not only heart rate (HR) signals 402, but also motion signals from body motion 404 and motion signals from user breathing 406. In Fig. 11B, active motion noise removal via one or more filters associated with the processor(s) 14 have removed the motion signals from body motion 404 and motion signals from user breathing 406. Noise attenuation and removal is described in detail in U.S. Patent No. 8,157,730, U.S. Patent No. 8,251,903, U.S. Patent Application Publication No. 2008/0146890, U.S. Patent Application Publication No. 2010/0217098, U.S. Patent Application Publication No. 2010/0217102, U.S. Provisional Patent Application No. 61/750,490, PCT Application No. US2012/071593, PCT Application No. US2012/071594, and PCT Application No. US2012/048079, which are incorporated herein by reference in their entireties.

If multiple wavelengths are used in PPG sensing, such as the case for pulse oximetry, then there will be multiple spectrograms with similar spectral profiles. And the ratio of functions of $A(\omega_{HR})_{\lambda 1}$ with respect to functions of $A(\omega_{HR})_{\lambda 2} \dots A(\omega_{HR})_{\lambda n}$ may be proportional to the concentration of various types of hemoglobin in the blood. For example, the SpO_2 concentration of blood may be proportional to $A(\omega_{HR})_{\lambda 1}/A(\omega_{HR})_{\lambda 2}$ (where $\lambda 1$ may be a shorter wavelength than $\lambda 2$) or a ratio of functions of these spectral amplitudes.

According to some embodiments of the present invention, signal quality from a sensor in the biometric monitoring device 10 can be determined by the following equation:

$$\text{Signal Quality} = Q_s \propto \frac{A(\omega_{HR})}{\sum A(\omega_i)}$$

In other words, signal quality Q_s is proportional to heart rate signal divided by the sum of the signal components associated with user motion.

This formula may be useful once a spectrogram is generated for a PPG signal collected by the sensor(s) 12. In the spectral domain, the signal quality Qs may be expressed as a ratio of the spectral amplitude at the HR frequency divided by a sum of various other spectral amplitudes that may also exist in the spectrogram. Similarly, the signal quality Qs may be related to a ratio of functions of various spectral amplitudes. The signal quality Qs may be assessed either before or after motion-artifact removal, but in the case of assessing signal quality post-motion-artifact removal, the sum of spectral amplitudes in the denominator is likely to be smaller than for the case of assessing signal quality pre-motion-artifact removal, as suggested by Fig. 11A and Fig. 11B. Thus, when there are less spectral artifacts from motion artifacts and other unwanted time-varying artifacts, the signal quality Qs is likely to be higher than for the case where many such artifacts are present.

The formula for assessing signal quality is not meant to be limiting. Various other formulas or methods may be used to assess signal quality according to embodiments of the present invention. For example, a different, simpler formula may assess only the magnitude of the spectral amplitude at the HR frequency. A different, more complicated formula may assess the ratio of 2 or more signal qualities, as calculated from the above formula for multiple PPG wavelengths. Additionally, a time-domain approach may be preferred in some embodiments. For example, the peak amplitude of a time-domain photoplethysmogram (such the PeakAC as shown in Fig. 9) may be calculated and used to assess signal quality, with higher PeakAC correlating with higher Qs. In the time domain, a more complicated method may be to assess Qs by the ratio: PeakAC/PeakCadence, where PeakCadence refers to the peak amplitude of an accelerometer output at the user's cadence (step rate, jumping rate, cycling rate, etc.). Additionally, the spectral and time-domain approaches described above for a PPG sensor may also be applied for the case where the sensors comprise an ECG sensor (such as that used in ECG leads, ECG chest straps or ECG wristbands) and an inertial sensor (such as an accelerometer).

Embodiments of the present invention may also be applied for measuring PPG from the ear canal, body temperature from the tympanic membrane, or various other biometrics at various locations of the body. For the case of an in-ear measurement, a user may be instructed via the wearable

monitor 10 and/or remote device 40 to wiggle their ear or talk while PPG or body temperature is being measured from the ear canal or tympanic membrane. The signal quality Qs may then be calculated for these activities to make certain the signal quality is above the minimum acceptable value. In contrast, a user
 5 measuring PPG and skin temperature at the leg may be instructed to stomp the leg while signal quality Qs is being assessed.

The processor(s) 14 may also determine that the position of the wearable device 10 is not sufficient for accurate biometric monitoring. For example, the processor 14 may process signal readings from an accelerometer
 10 12 to determine if the wearable device is being worn correctly with respect to the ground. One methodology for determining the location of ground via an accelerometer may be to assess three (3) or more axes of the accelerometer to determine the vector of 1G of force, using commonly known trigonometric methods, and then to assess whether that vector is sufficiently aligned with a
 15 desired vector for that 1G of force. For example, it may be desired that an accelerometer placed in an earbud have ~1G of force directly along the Z-vector. If the location of the 1G of force is found by the processor to be close enough to the axis along the Z-vector, then the processor may determine that the earbud is being worn properly (Fig. 5B, 6B, & 7A); otherwise, the processor may determine
 20 that the earbud is not being worn properly (Fig. 5A, 6A, & 7B). In some cases, determining that the subject is wearing the monitoring device 10 appropriately may involve audio-visual feedback from the monitoring device 10 and/or a remote device 40. For example, a prompt may notify the a user to wear a wristband with the sensor region 34 located at a certain spot along the wrist. The
 25 processor 14 may then determine whether the device is being worn appropriately in accordance with the audio-visual instructions.

Fig. 12 is an exemplary plot 500 of signal quality Qs (as may be determined by methods described earlier as well as other methods) over time for an exemplary run by a user wearing a biometric monitoring device 10. The
 30 dotted line 502 represents the minimum signal quality Qs that is acceptable for producing accurate physiological information. The signal quality Qs may dip below the minimum acceptable quality during certain aspects of the run, such as during erratic running motion or high ambient light interference. The processor(s) 14 may determine that the signal quality Qs is too low for the measured

biometric to be accurate, preventing the errant biometric reading from being applied towards a physiological assessment. For example, post analysis on the running data generated by the sensor(s) 12 in the wearable biometric monitoring device 10 may be generated by processing biometrics (heart rate, breathing rate, R-R interval, HRV, blood pressure, etc.) and activity metrics (cadence, speed, pace, distance, total steps, etc.) together. As a specific example, by processing heart rate and cadence together over time, the processor(s) 14 may determine when the user has started and stopped an exercise and may then determine the user's heart rate recovery (the change in heart rate from the stop of exercise and 1 minute or more following the stop of exercise). But, if the signal quality Q_s is determined to be below the minimum allowable level of quality during the relevant data collection period (in this case the period between the stop of the exercise and a minute or more afterwards), then the processor(s) 14 may determine that heart rate recovery cannot be accurately determined.

Alternatively, the processor(s) 14 may estimate the heart rate recovery with the errant data along with an assessment that the confidence of the estimation is poor, and both of the estimate and signal quality may be reported to the user audio-visually.

Fig. 13 is a plot 500 of signal quality Q_s over time for a user conducting a self-fitting test, according to some embodiments of the present invention. The dotted line 502 represents the minimum signal quality Q_s that is acceptable for producing accurate physiological information. The illustrated plot 500 can be presented to the user via a display in a remote device 40 in communication with the biometric monitoring device 10.

At time t_0 , the user attaches the biometric monitoring device 10 to his/her body (e.g., inserts earbud sensor module in ear, straps on a wristband sensor module, etc.) and turns the biometric monitoring device on. At time t_a , the user receives the first indication of signal quality and, as illustrated, it is below the minimum signal quality line 502. At time t_b , the user makes one or more adjustments to the biometric monitoring device at this point to improve the signal quality. For example, the user repositions the biometric monitoring device 10 relative to the body, adds a spacer or gel device to create a better fit relative to the body, tightens a strap securing the biometric monitoring device 10 to the body, etc. As a result of the user adjustment, the signal quality improves as

illustrated between time t_b and time t_c .

However, as illustrated in Fig. 13, the user continues to adjust the biometric monitoring device 10 and the signal quality falls below the minimum signal quality line 502 by time t_d . The user continues adjustment of the biometric monitoring device until the signal quality is raised above the minimum signal quality line 502. At time t_e , the user is happy with the signal quality and keeps the biometric monitoring device 10 in place.

Fig. 14 is a plot 500 of signal quality Q_s over time for a user conducting an instructed "quick test" regimen, according to some embodiments of the present invention. The dotted line 502 represents the minimum signal quality Q_s that is acceptable for producing accurate physiological information. The illustrated plot 500 can be presented to the user via a display in a remote device 40 in communication with the biometric monitoring device 10.

At time t_0 , the user attaches the biometric monitoring device 10 to his/her body (e.g., inserts earbud sensor module in ear, straps on a wristband sensor module, etc.) and turns the biometric monitoring device on. At time t_a , the user is instructed to execute a "quick test" regimen, such as running in place for a short period of time (e.g., 15 seconds, etc.). As illustrated, between the time t_a and t_b , the signal quality is above the minimum line 502, and this is because the user is at rest and motion artifacts are not impairing the signal 500. However, when the user starts the "quick test" regimen (i.e., running in place), the signal quality falls below the minimum signal quality line 502. The user is then instructed to adjust the biometric monitoring device 10 at time t_d (e.g., reposition the biometric monitoring device 10 relative to the body, add a spacer or gel device to create a better fit relative to the body, tighten a strap securing the biometric monitoring device 10 to the body, etc.) and repeat the "quick test" regimen (e.g., running in place). As a result of the user adjustment, the signal quality improves as illustrated at time t_e . The signal quality remains above the minimum signal quality line 502 at time t_f after the "quick test" regimen.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the teachings and advantages of this invention.

Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

THAT WHICH IS CLAIMED IS:

1. A method of monitoring signal quality of a wearable biometric monitor, wherein the monitor includes at least one sensor configured to
5 detect and/or measure physiological information from a subject wearing the biometric monitor and at least one processor coupled to the at least one sensor that is configured to receive and analyze signals produced by the at least one sensor, the method comprising the following steps performed via the at least one processor:
10 instructing the subject to begin an exercise regimen;
 measuring signal quality produced by the at least one sensor during the exercise regimen; and
 communicating information to the subject regarding the signal quality during the exercise regimen.
15
2. The method of Claim 1, wherein communicating information to the subject regarding the signal quality comprises communicating instructions to the subject to adjust the biometric monitor relative to the body of the subject if the signal quality is below a threshold level.
20
3. The method of Claim 1, wherein communicating information to the subject regarding the signal quality comprises communicating information to the subject that the signal quality is above a threshold level.
- 25 4. The method of Claim 1, wherein instructing the subject to begin an exercise regimen comprises sending an audio and/or visual communication to a remote device in communication with the biometric monitor.
5. The method of Claim 1, wherein communicating information
30 to the subject regarding the signal quality comprises sending an audio and/or visual communication to a remote device in communication with the biometric monitor.

6. The method of Claim 1, wherein instructing the subject to begin an exercise regimen comprises causing the biometric monitor and/or a remote device to vibrate.

5 7. The method of Claim 1, wherein communicating information to the subject regarding the signal quality comprises causing the biometric monitor and/or a remote device to vibrate.

8. The method of Claim 1, wherein the biometric monitor
10 includes an actuator, and further comprising automatically adjusting the biometric monitor relative to the body of the subject via the actuator if the signal quality is below a threshold level.

9. The method of Claim 1, wherein the biometric monitor
15 includes a motion sensor, and further comprising determining if the subject has begun the exercise regimen by detecting a change in subject activity via the motion sensor.

10. The method of Claim 1, wherein the biometric monitor is
20 configured to be integrated within an earbud.

11. The method of Claim 1, wherein the biometric monitor is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

25

12. The method of Claim 1, wherein the biometric monitor comprises a band configured to at least partially encircle a portion of the body of a subject, and wherein the portion of the body comprises a limb, a nose, an earlobe, and/or a digit.

30

ABSTRACT OF THE DISCLOSURE

A wearable biometric monitoring device is configured to assess the biometric signal quality of one or more sensors associated with the monitoring device, determine how the user should adjust the device to improve the biometric fit, and instruct the user to wear the biometric monitoring device a
5 certain way. Communicating instructions to a user may include instructing the user to execute a testing regimen while wearing the biometric monitoring device. The testing regimen facilitates an estimation of a signal quality that can be used to provide feedback to the user that he/she needs to adjust the device to improve the biometric fit and the biometric signal quality.

1579722

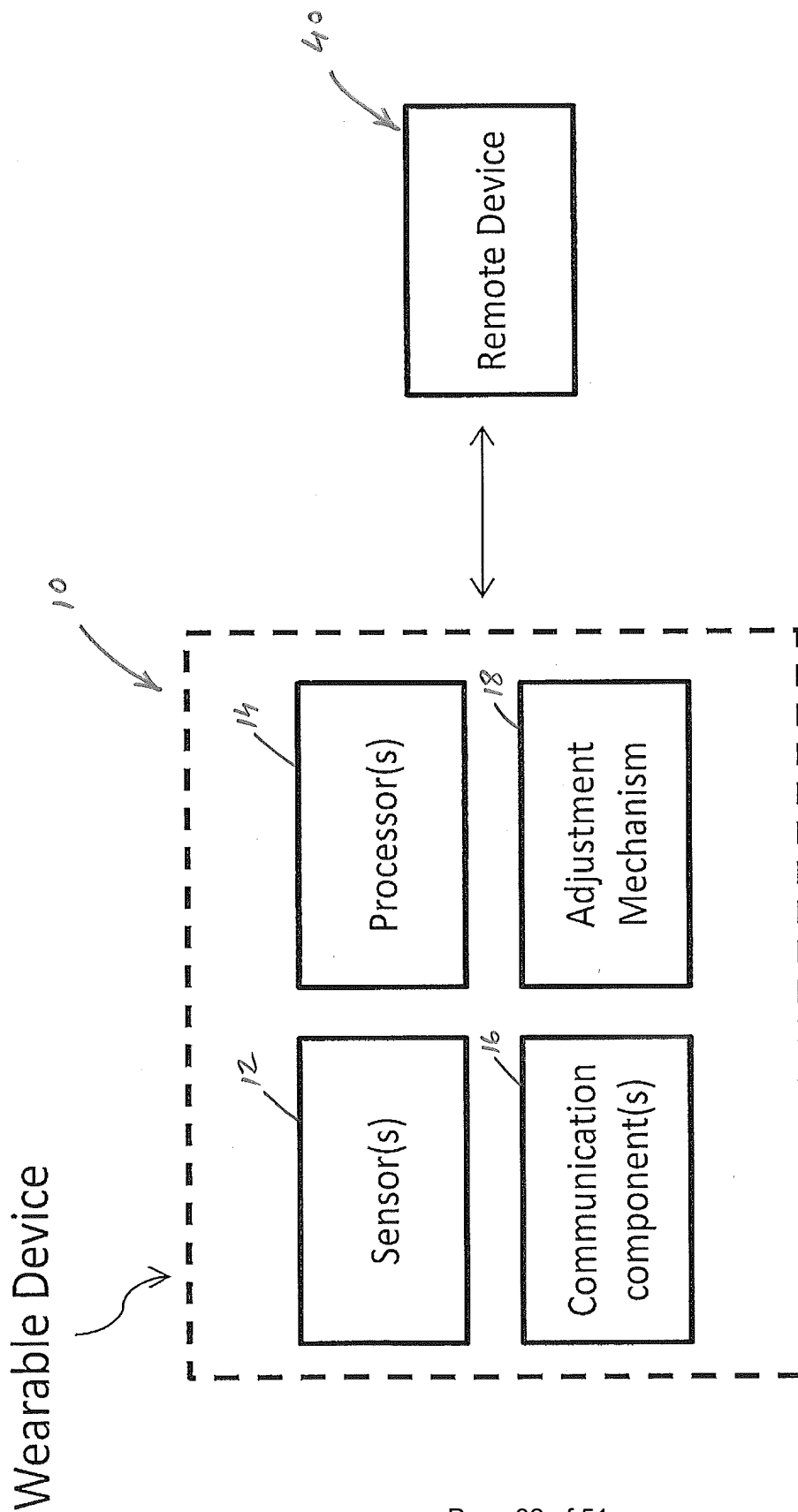


FIG. 1

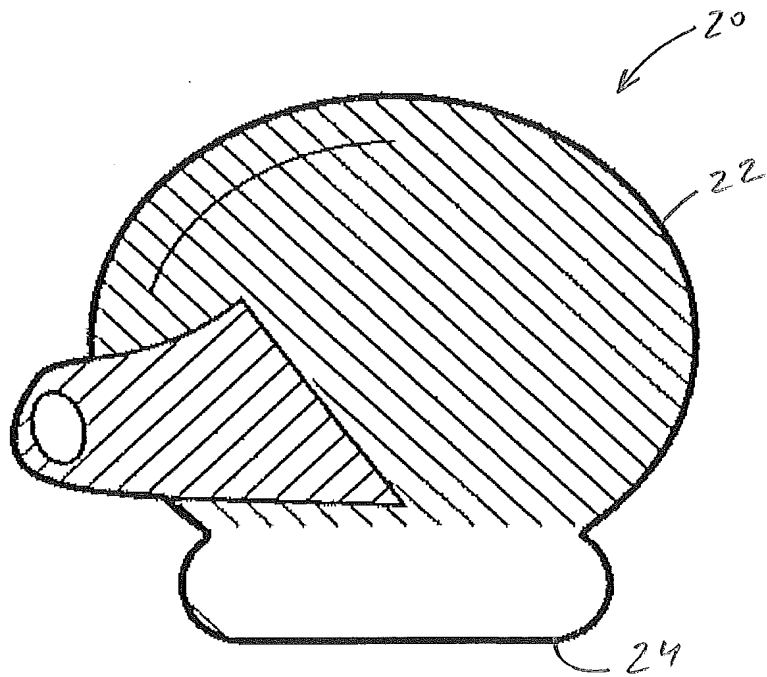


FIG. 2

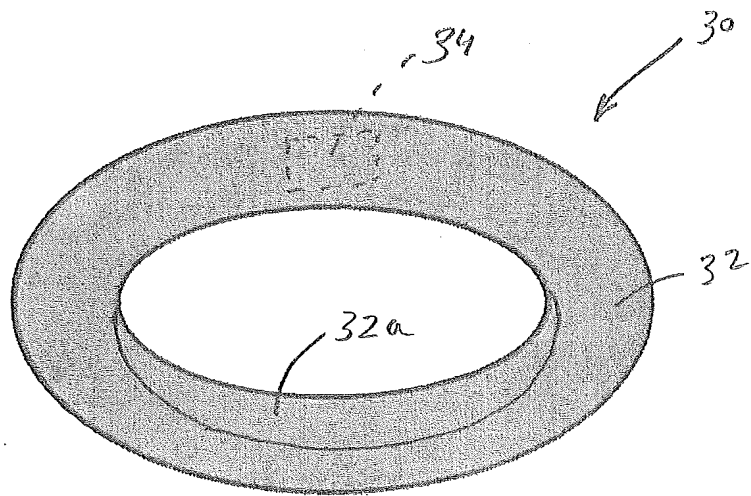


FIG. 3

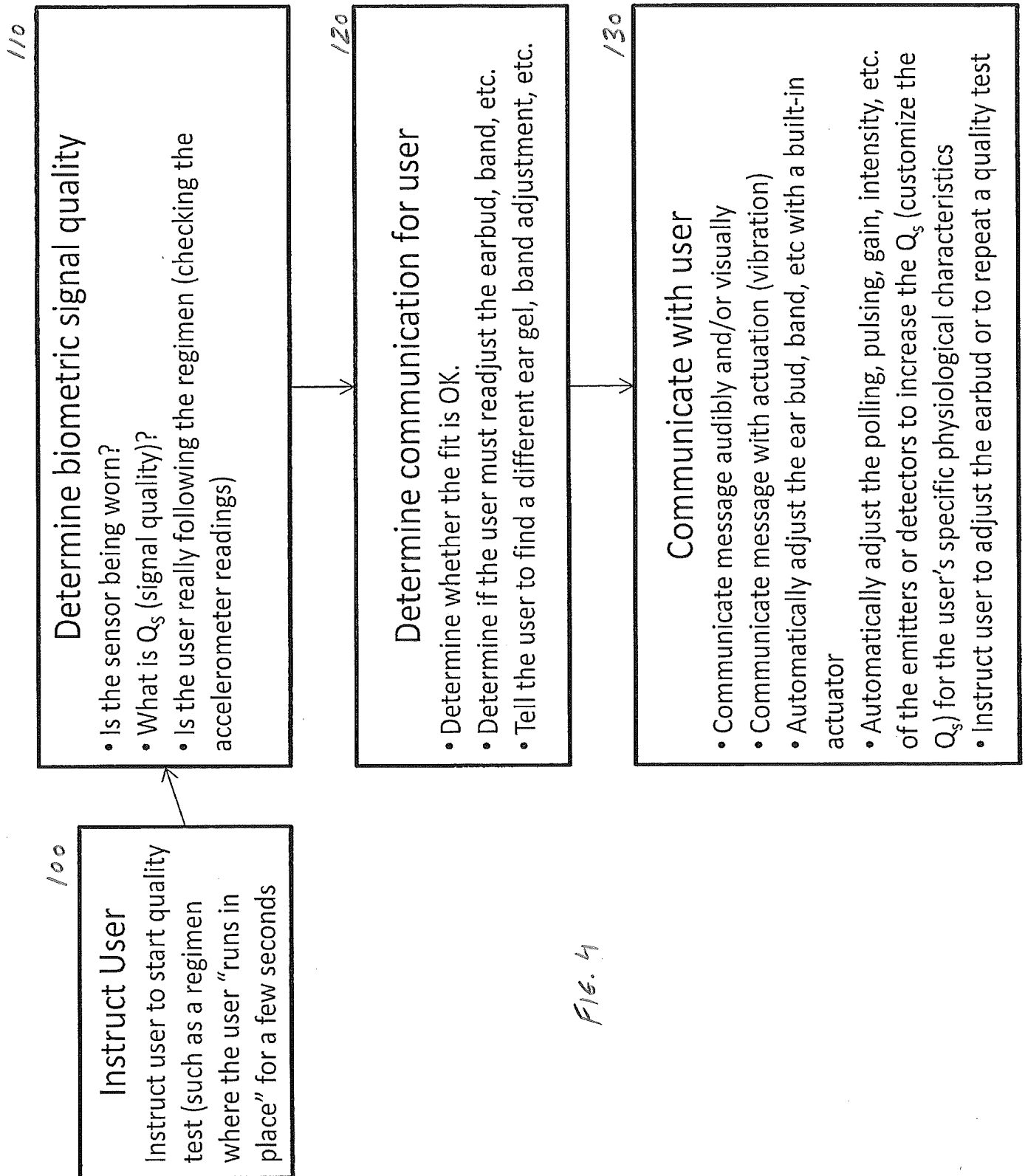
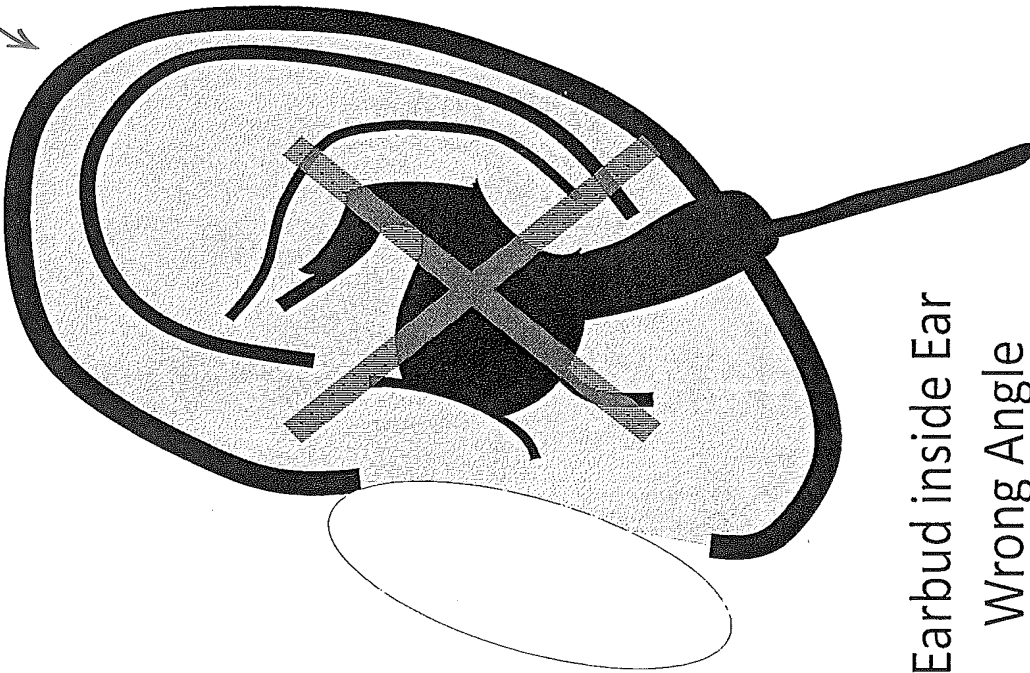


Fig. 4

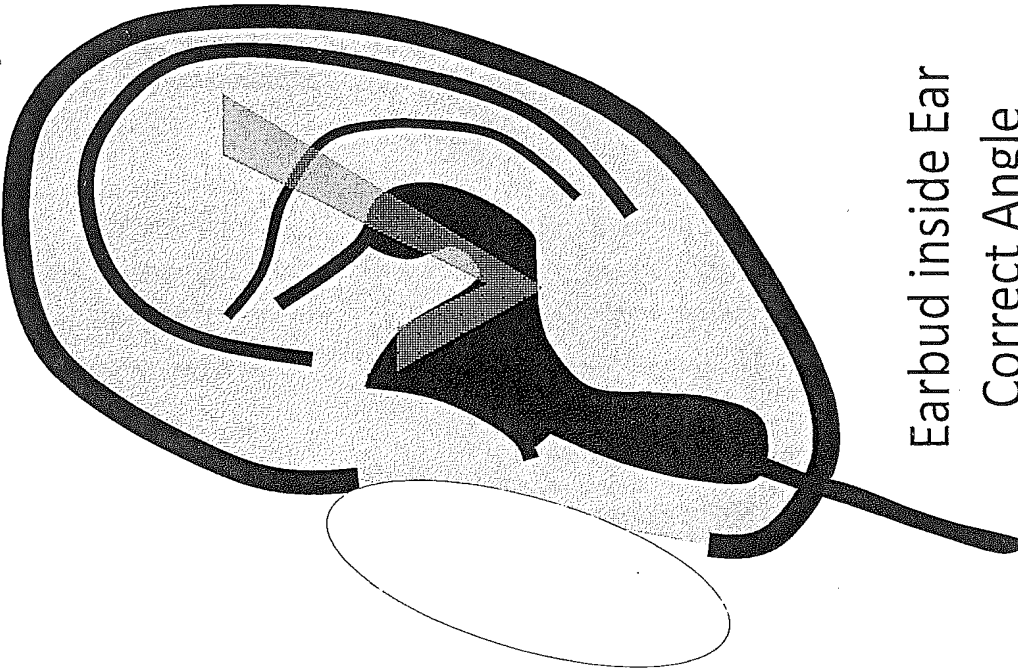
200



Earbud inside Ear
Wrong Angle

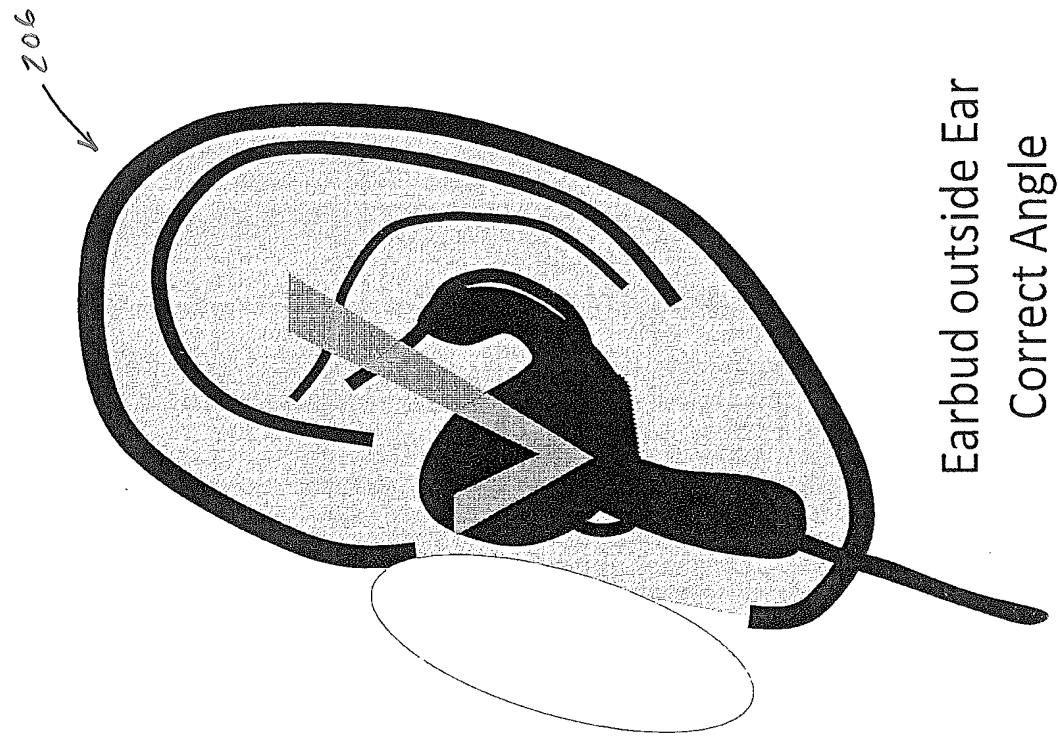
FIG. 5A

202



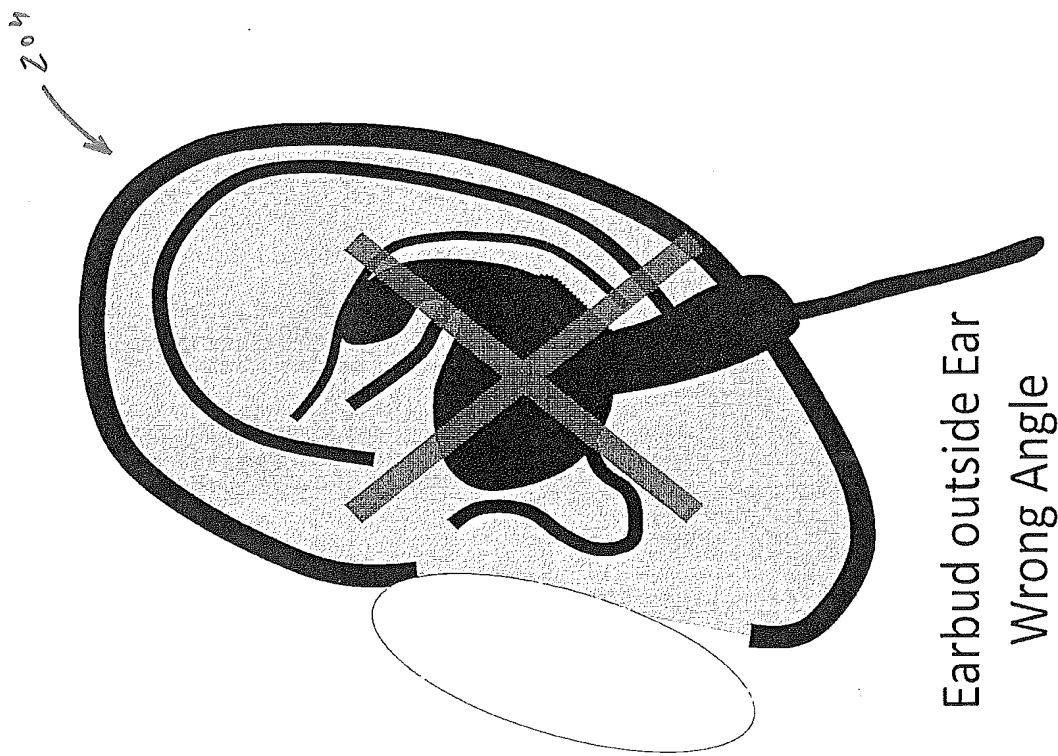
Earbud inside Ear
Correct Angle

FIG. 5B



Earbud outside Ear
Correct Angle

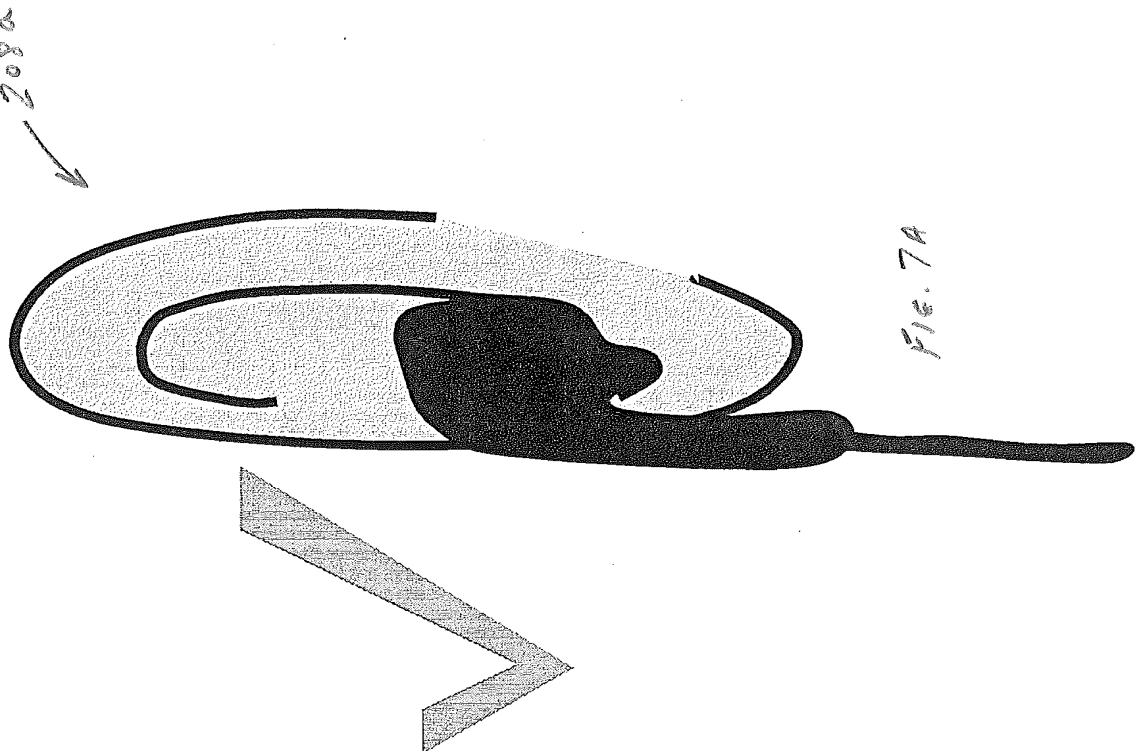
FIG. 6B



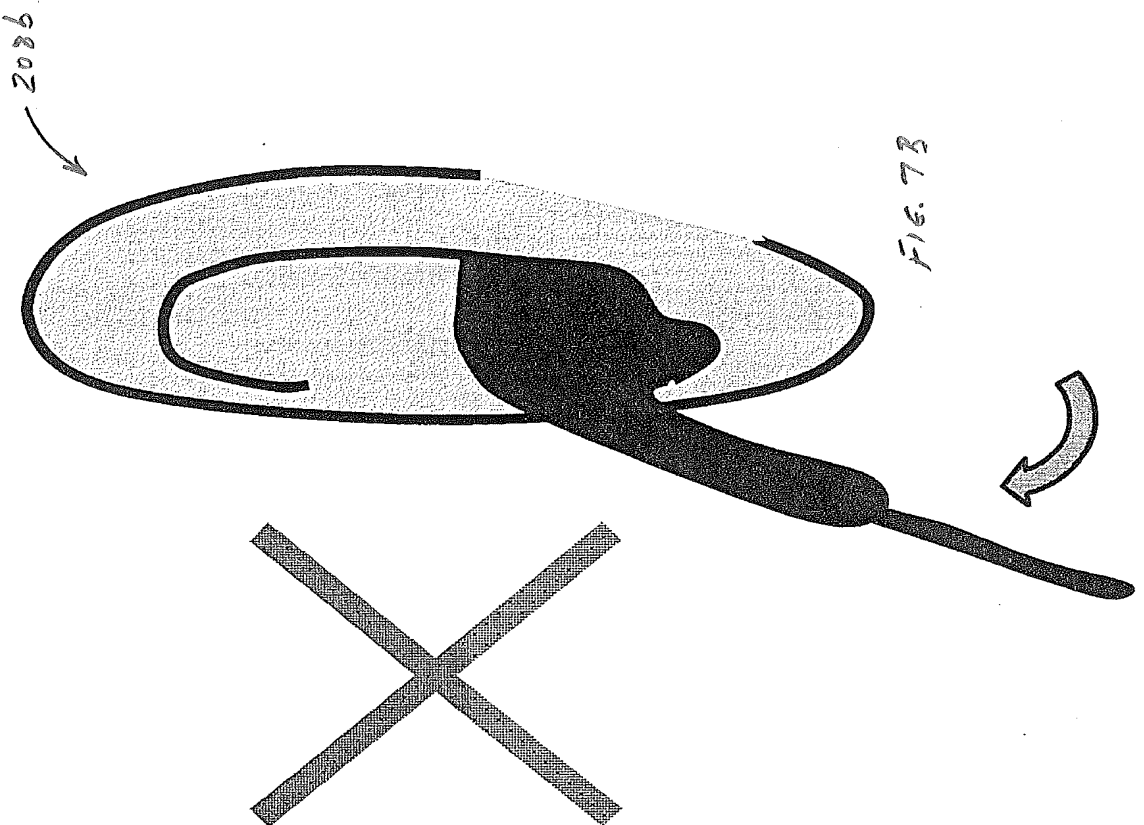
Earbud outside Ear
Wrong Angle

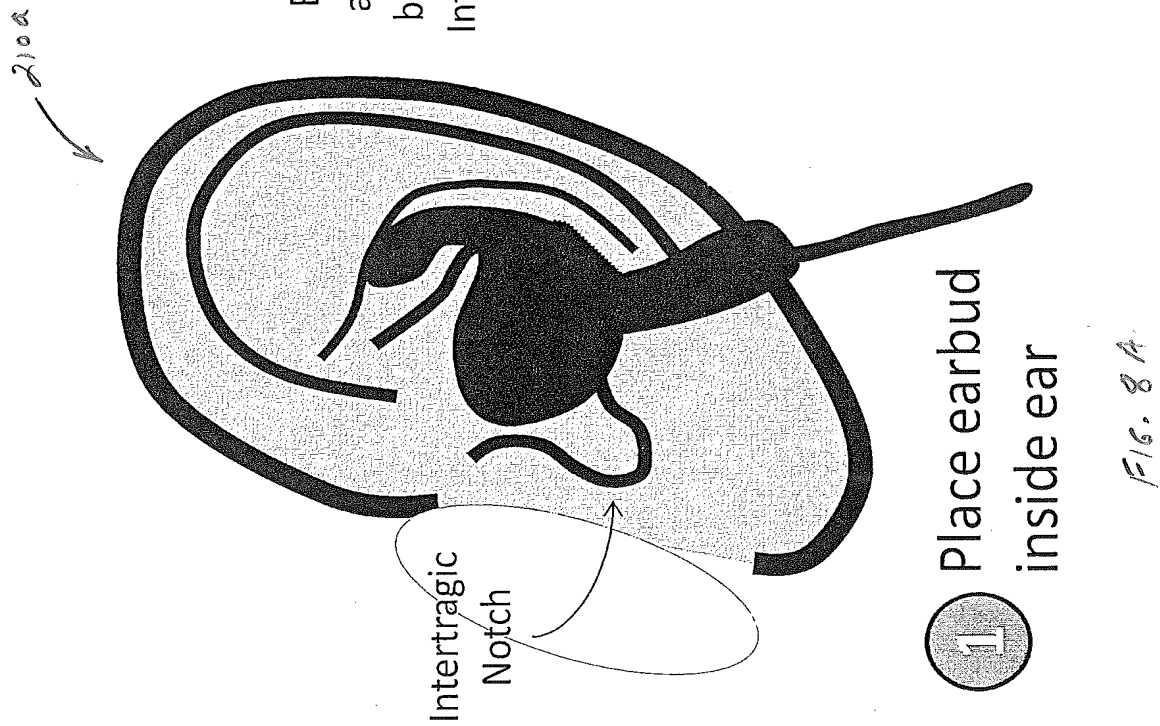
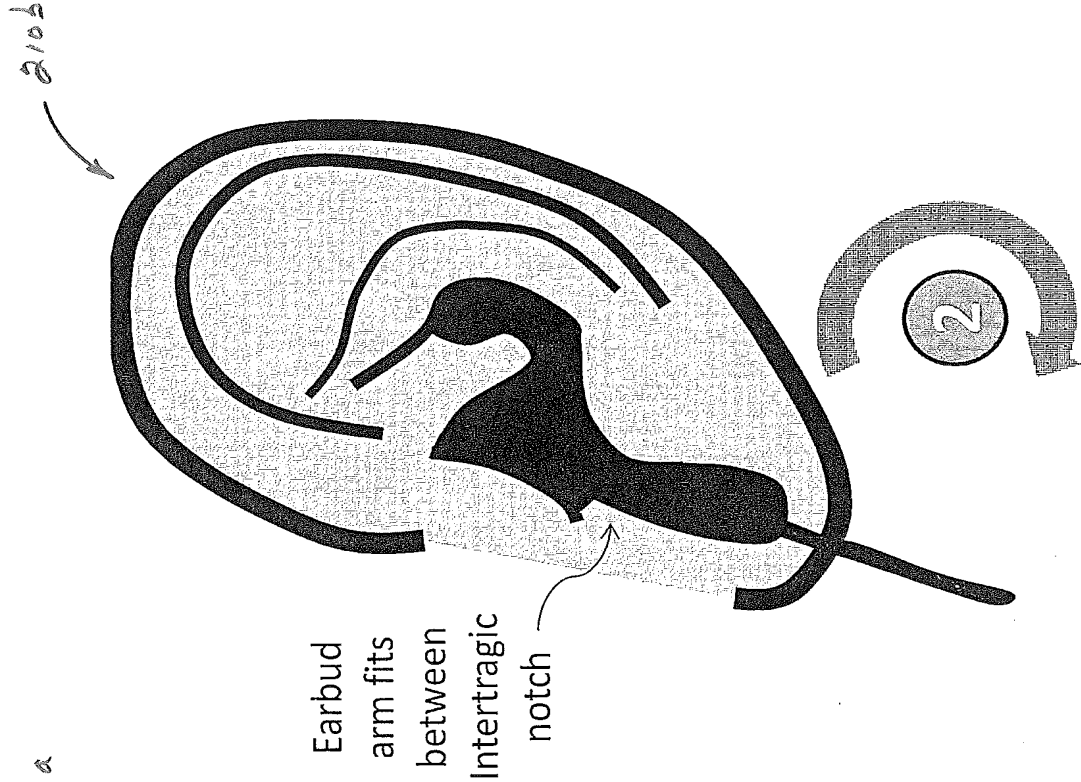
FIG. 6A

1 Place earbud flush
inside right ear



2 Do not place earbud
at outward angle





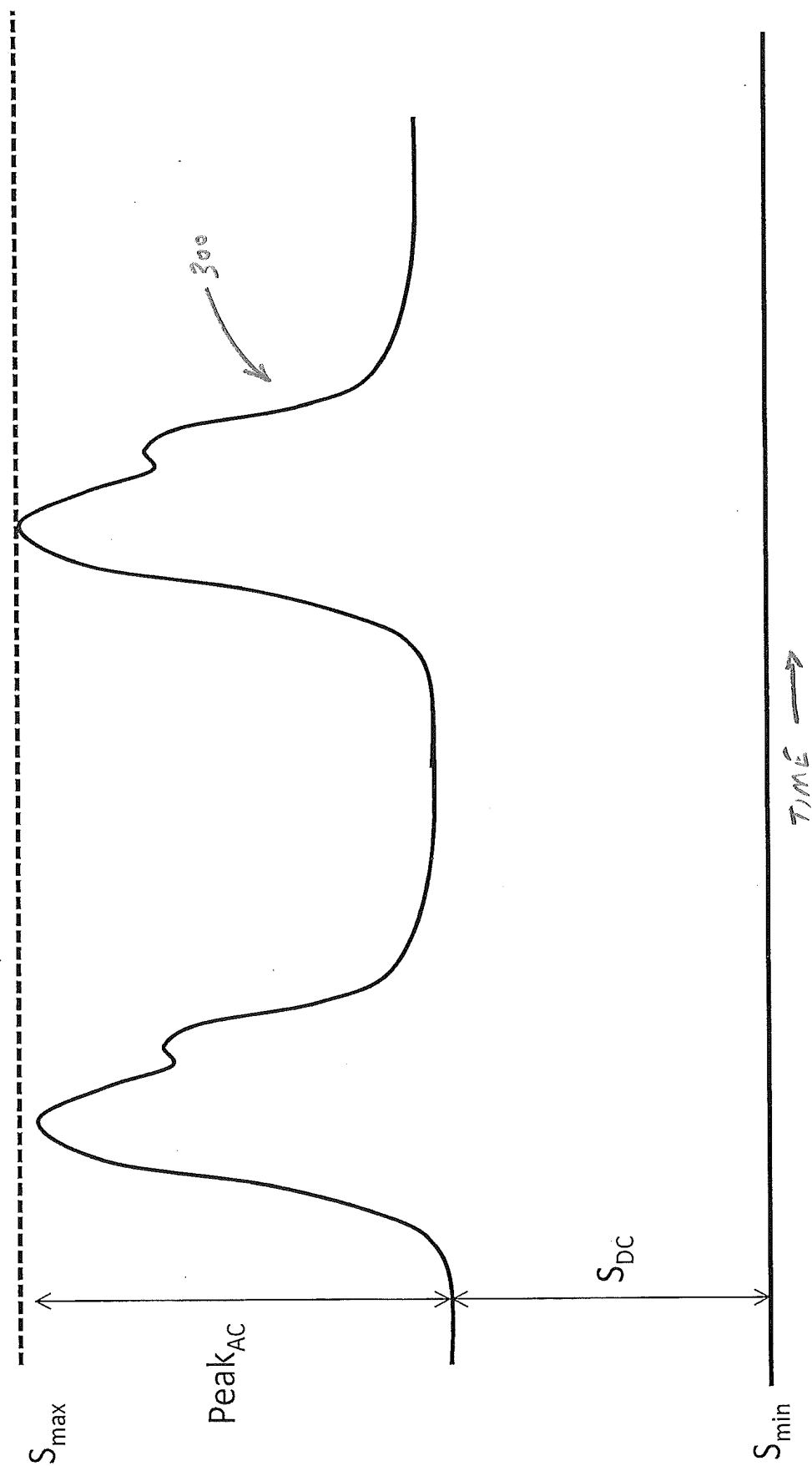
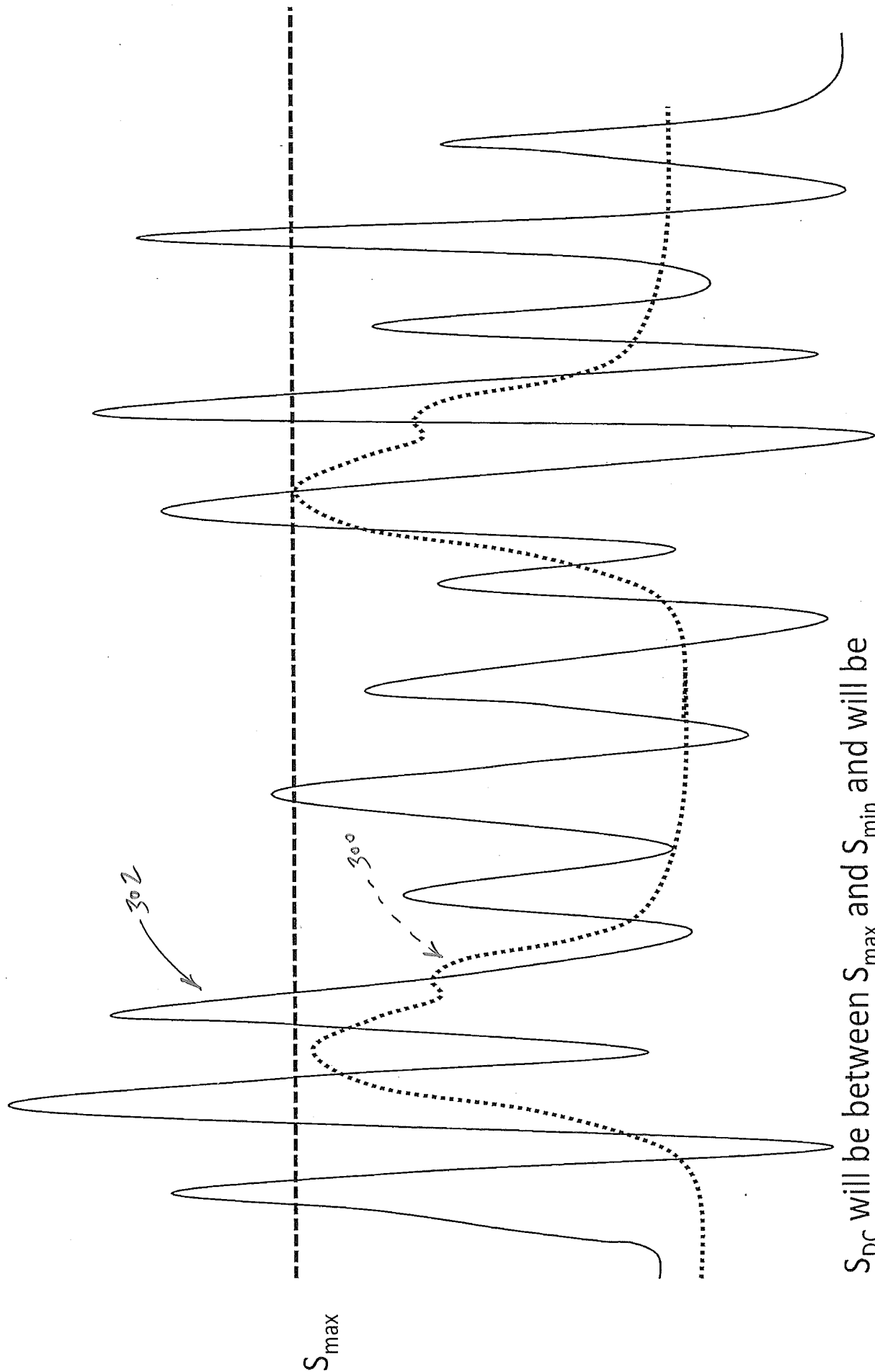


FIG. 9



S_{DC} will be between $S_{\max}$ and $S_{\min}$ and will be time-varying with blood flow and body motion

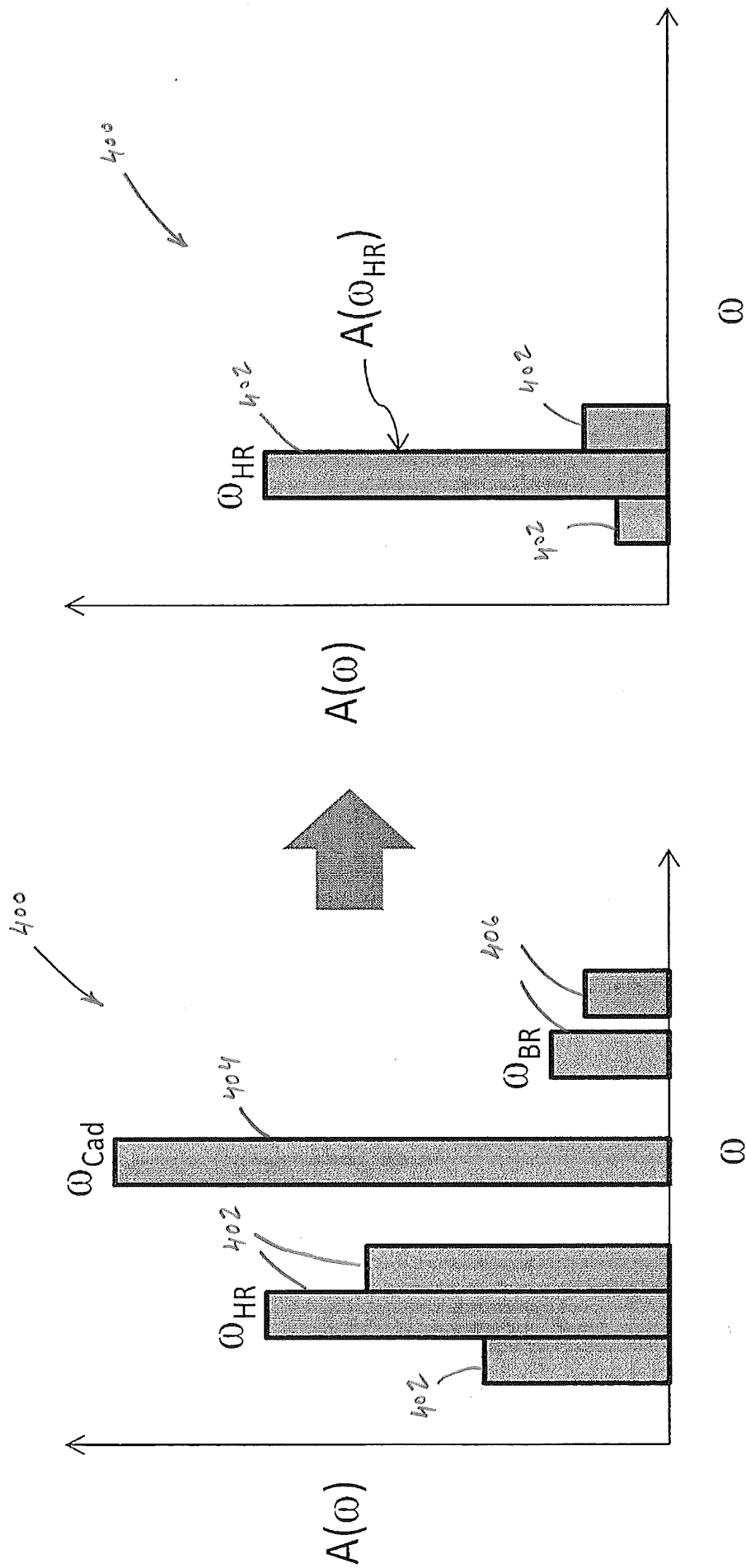


FIG. 11B

FIG. 11A

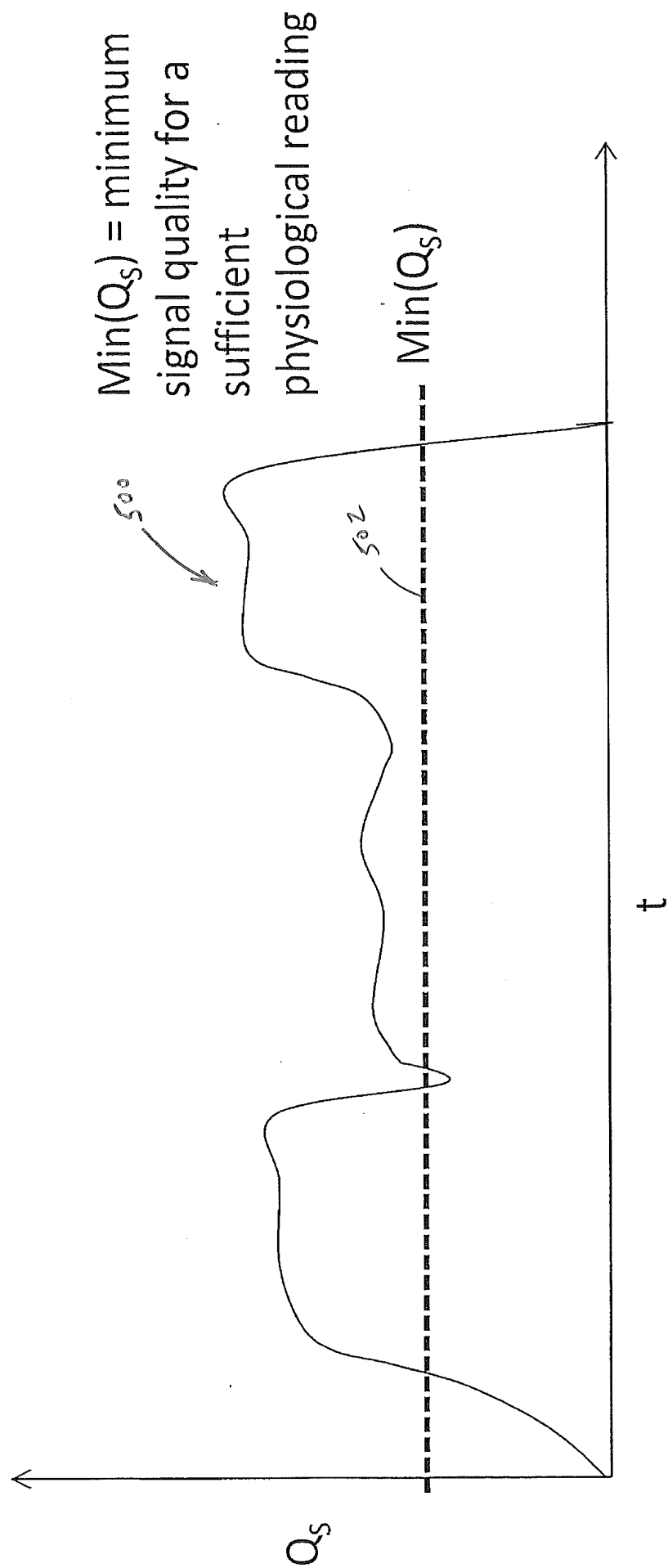


FIG. 12

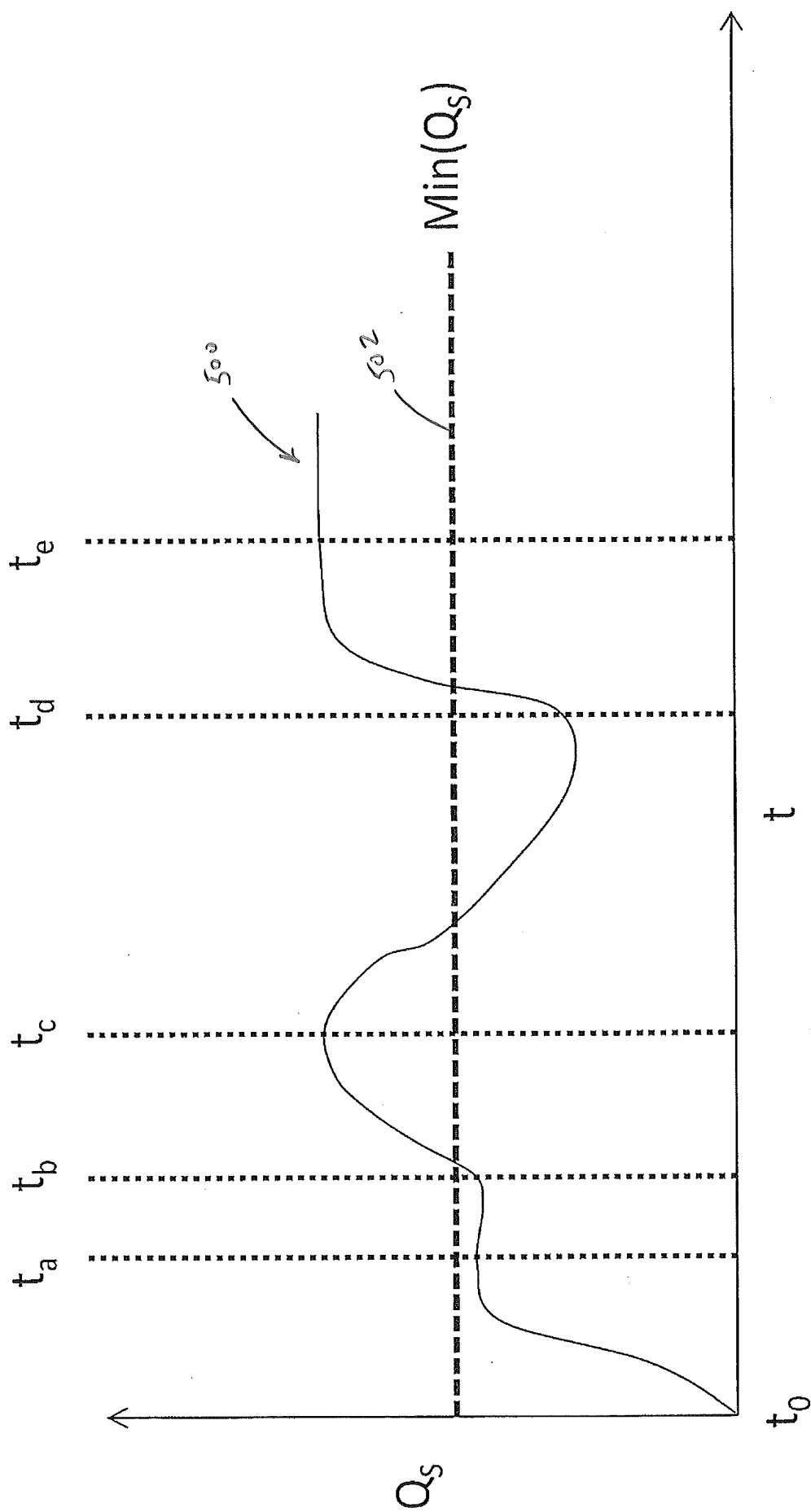


FIG. 13

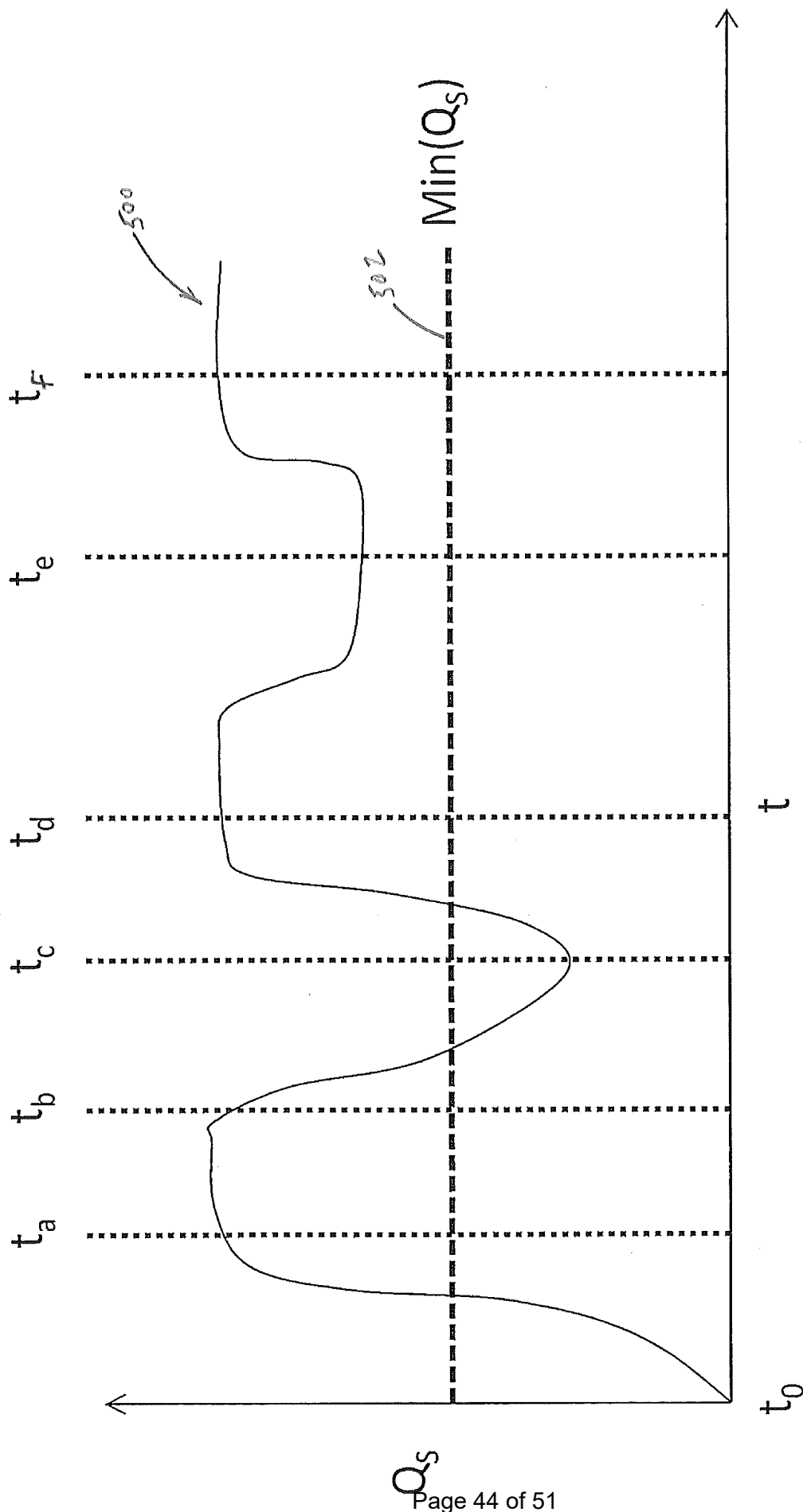


FIG. 14

Electronic Patent Application Fee Transmittal

Application Number:

Filing Date:

Title of Invention:

METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES

First Named Inventor/Applicant Name:

Steven Francis LeBoeuf

Filer:

Needham J. Boddie/Susan E. Freedman

Attorney Docket Number:

9653-30PR

Filed as Large Entity

Provisional Filing Fees

Description

Fee Code

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**Sub-Total in
USD(\$)**

Basic Filing:

Provisional Application Filing

1005

1

260

260

Pages:

Claims:

Miscellaneous-Filing:

Petition:

Patent-Appeals-and-Interference:

Post-Allowance-and-Post-Issuance:

Extension-of-Time:

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				260

Electronic Acknowledgement Receipt

EFS ID:	20263826
Application Number:	62056510
International Application Number:	
Confirmation Number:	2032
Title of Invention:	METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC MONITORING DEVICES
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie/Susan E. Freedman
Filer Authorized By:	Needham J. Boddie
Attorney Docket Number:	9653-30PR
Receipt Date:	27-SEP-2014
Filing Date:	
Time Stamp:	13:09:16
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$ 260
RAM confirmation Number	6651
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File Listing:

Document Number	Document Description	Page 47 of 51	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
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1	Transmittal of New Application	9653-30PR_2014-09-27_Transmittal.pdf	212441 1beddcf8a2e52d15ad2acab6f074cbb1ef9181bc	no	2
Warnings:					
Information:					
2	Application Data Sheet	9653-30PR_2014-09-27_ADS.pdf	725791 af8d4f28fd2e678c68b691184e0468d174a960ce	no	6
Warnings:					
Information:					
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3	Specification	9653-30PR_2014-09-27_Specification.pdf	2711733 862e1c6440b1a514f5a07055af463957d6c1d571	no	23
Warnings:					
Information:					
4	Drawings-only black and white line drawings	9653-30PR_2014-09-27_Drawings.pdf	1293447 fe3869f2b782707745900e332d1ef1365b62c31e	no	13
Warnings:					
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5	Fee Worksheet (SB06)	fee-info.pdf	30193 810f16dad6bc31613bd5518cf819c4b0f0f6fa58	no	2
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
62/056,510	09/27/2014		260	9653-30PR		

CONFIRMATION NO. 2032

20792
MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

FILING RECEIPT



Date Mailed: 10/09/2014

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Inventor(s)

Steven Francis LeBoeuf, Raleigh, NC;
Michael Edward Aumer, Raleigh, NC;

Applicant(s)

Valencell, Inc., Raleigh, NC

Power of Attorney:

Needham Boddie II--40519

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Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No
Title

METHODS AND APPARATUS FOR IMPROVING SIGNAL QUALITY IN WEARABLE BIOMETRIC
MONITORING DEVICES

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

page 1 of 3

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